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SHORELINE PLANT ESTABLISHMENT AND USE OF A WAVE-STILLING DEVICE--ETC(U)
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Shoreline Plant Establishment and Use of a Wave-Stilling Device

by

J.W. Webb and J.D. Dodd

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The establishment and development of smooth cordgrass transplants on a 2-percent slope behind a wave-stilling device constructed of two tiers of tires strung on a cable were monitored along the north shore of East Bay in Texas. Two previous plantings on the sloped area, the first without wave protection and the second behind one tier of tires, were unsuccessful. After a second tier of tires was placed on top of the original tier, enough protection was provided from waves to allow successful planting. A 0.15-meter buildup of sediment occurred directly ~~being~~ behind the barrier. (continued)

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Smooth cordgrass survival was approximately 50 percent and over 100 stems per meter squared were counted in some areas 1 year after planting. Density and height of smooth cordgrass increased with increasing hours of inundation. Rabbits apparently caused enough damage to plants outside a rabbit-proof fence that significant differences in density between fenced and unfenced areas occurred.

Gulf cordgrass, marshhay cordgrass, and saltgrass survived better than smooth cordgrass above mean high water (MHW). At the highest elevation (0.6 meter above MHW), survival was limited, regardless of species. Needlegrass rush transplants failed to survive in significant numbers. Cost per linear meter of shoreline for establishing the wave-stilling device and planting the area was $15.90.

Previous plantings were evaluated in June 1977. Smooth cordgrass density had declined in block IV; saltcedar and giant reed continued to do well above MHW; and needlegrass rush had multiplied profusely in the one area of survival. Smooth cordgrass survived in one wave-exposed area where the soil was covered with rock and shell.

With adequate wave protection, smooth cordgrass can be established below MHW in estuarine areas. Gulf cordgrass, marshhay cordgrass, and saltgrass can be used above MHW for shoreline protection.

PREFACE

This report is published to assist coastal engineers in shoreline stabilization through the establishment and maintenance of vegetation. The techniques for shoreline stabilization with vegetation and the use of wave-stilling devices discussed in this report are applicable to other estuarine areas. The research was carried out under the coastal ecology research program of the U.S. Army Coastal Engineering Research Center (CERC). This report is the third in a series of three reports on this effort. Previous research is reported in CERC MP 6-75 and CERC TP 76-13.

The report was prepared by J.W. Webb, Research Associate in Range Science, and J.D. Webb, Professor of Range Science, Texas A&M University, under CERC Contract No. DACW72-74-C-0002. Support was also received from the Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas 77843.

The authors express appreciation for the cooperation of personnel at the Anahuac National Wildlife Refuge, particularly R. Clapper, Manager. Special thanks are due A.T. Weichert, B.H. Koerth, and W. Cleary, for their assistance in fieldwork.

A.K. Hurme was the CERC contract monitor for the report under the general supervision of R.M. Yancey, Chief, Ecology Branch, Research Division.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

John H. Cousins

JOHN H. COUSINS
Colonel, Corps of Engineers
Commander and Director

CONTENTS

TABLES

FIGURES

CONTENTS

FIGURES-Continued

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.8532	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.1745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1]To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

SHORELINE PLANT ESTABLISHMENT AND USE OF A WAVE-STILLING DEVICE

by

J. W. Webb and J. D. Dodd

I. INTRODUCTION

1. General.

Erosion has been a dominant process along the shorelines of Galveston Bay, Texas, for some time. Some areas have been recorded as eroding at the rate of 1.2 meters annually (Beach Erosion Board, 1954). Texas has over 2,880 kilometers of bay and gulf shorelines and nearly one-third of the population and industry are located in the coastal zone (Fisher, et al., 1972). Thus, considerable concern exists for a solution to shoreline erosion problems.

Recent research on the establishment of vegetation has shown that some plant species can be successfully transplanted from existing marshes and low-lying areas to inundated areas (Woodhouse, Seneca, and Broome, 1972, 1974; Mason, 1973; Garbisch, Woller, and McCallum, 1975; Dodd and Webb, 1975; Webb and Dodd, 1976). Previous reports by Phillips and Eastham (1959) and Sharp and Vaden (1970) described the sloping and planting of shorelines along tidal rivers in Virginia. These plantings were only partially successful. Sharp and Vaden concluded that smooth and marshhay cordgrasses (*Spartina alterniflora* and *S. patens*) were the best adapted plants for stabilizing beach areas.

Chapman (1967) attempted to vegetate a dredged-material island in Galveston Bay with transplants of smooth cordgrass. Transplants appeared to establish and spread.

Salt marsh establishment and development on shores and dredged materials in the mid-Chesapeake Bay region were investigated by Garbisch, Woller, and McCallum (1975). They reported no limitations for vegetation establishment above mean high water (MHW). Establishment of smooth cordgrass in intertidal zones was restricted by wave action and coarse sediment stresses.

2. Previous Work at Site.

Two previous reports by the authors on shoreline stabilization with plants have been published (Dodd and Webb, 1975; Webb and Dodd, 1976). Dodd and Webb (1975) concluded that smooth cordgrass was ideally suited for growth below MHW. Giant reed (*Arundo donax*) and gulf cordgrass (*S. spartinae*) were adapted for use in the upper zone, above MHW. Saltgrass (*Distichlis spicata*) may be used at intermediate elevations if wave action is low.

Webb and Dodd (1976) concluded that smooth cordgrass survival was significantly greater behind wave-stilling devices or in protected areas than in unprotected areas. Although plantings behind wave-stilling devices were initially successful, the devices became ineffective for wave protection shortly after construction. A technique for mechanical planting of single culms was used. Soil texture, pH, salinity, and cation concentrations were also reported for the study area.

3. Objectives of Studies

During the initial phases of the studies four objectives were established: (a) Isolate candidate planting materials known or believed to have utility for shoreline stabilization; (b) field test candidate planting materials on sites typical of shorelines along the upper Texas coast; (c) refine present knowledge on germination requirements, planting technology, and stand management of selected plants; and (d) compile a preliminary performance estimate equating time requirements and accomplishment for particular operations (Dodd and Webb, 1975).

This study further evaluates survival and establishment of transplants, and reports on plant survival and growth in a sloped and wave-protected demonstration area established in May 1976.

II. DESCRIPTION OF AREA

The Galveston Bay complex is composed of Galveston Bay and West Bay protected by Galveston Island, East Bay protected by Bolivar Peninsula, and Trinity Bay at the mouth of the Trinity River. Central parts of the bays have a maximum depth of approximately 3 meters with soft mud bottoms. East Bay and West Bay are both shallow, usually less than 1.8 meters deep, and are 4.8 to 5.6 kilometers wide (LeBlanc and Hodgson, 1959). The bay shoreline generally lacks sand beaches and in many places is associated with low-lying marshes. Experimental plantings were located at the Anahuac National Wildlife Refuge, which is situated along the north shoreline of East Bay in Chambers County, Texas (Figs. 1 and 2).

Soil and water parameters were measured along the shoreline of the refuge in 1973. Soil textures were generally loam in the upper 5 centimeters and clay loam in the 5- to 15-centimeter depth (Dodd and Webb, 1975). In most sites the percent sand exceeded that of other particle-size classes. Clay particles occurred in smallest quantities; therefore, these soils are considered highly erodible.

Soil pH was generally about 7.0 but varied slightly at different sampling dates (Webb and Dodd, 1976). Soil salinity increased or decreased with corresponding increases or decreases in bay water salinity. Differences in soil salinity at various depths and elevations were apparently related to changes in water salinity. Water salinity was directly related to dilution by rainfall and concentration by evaporation,

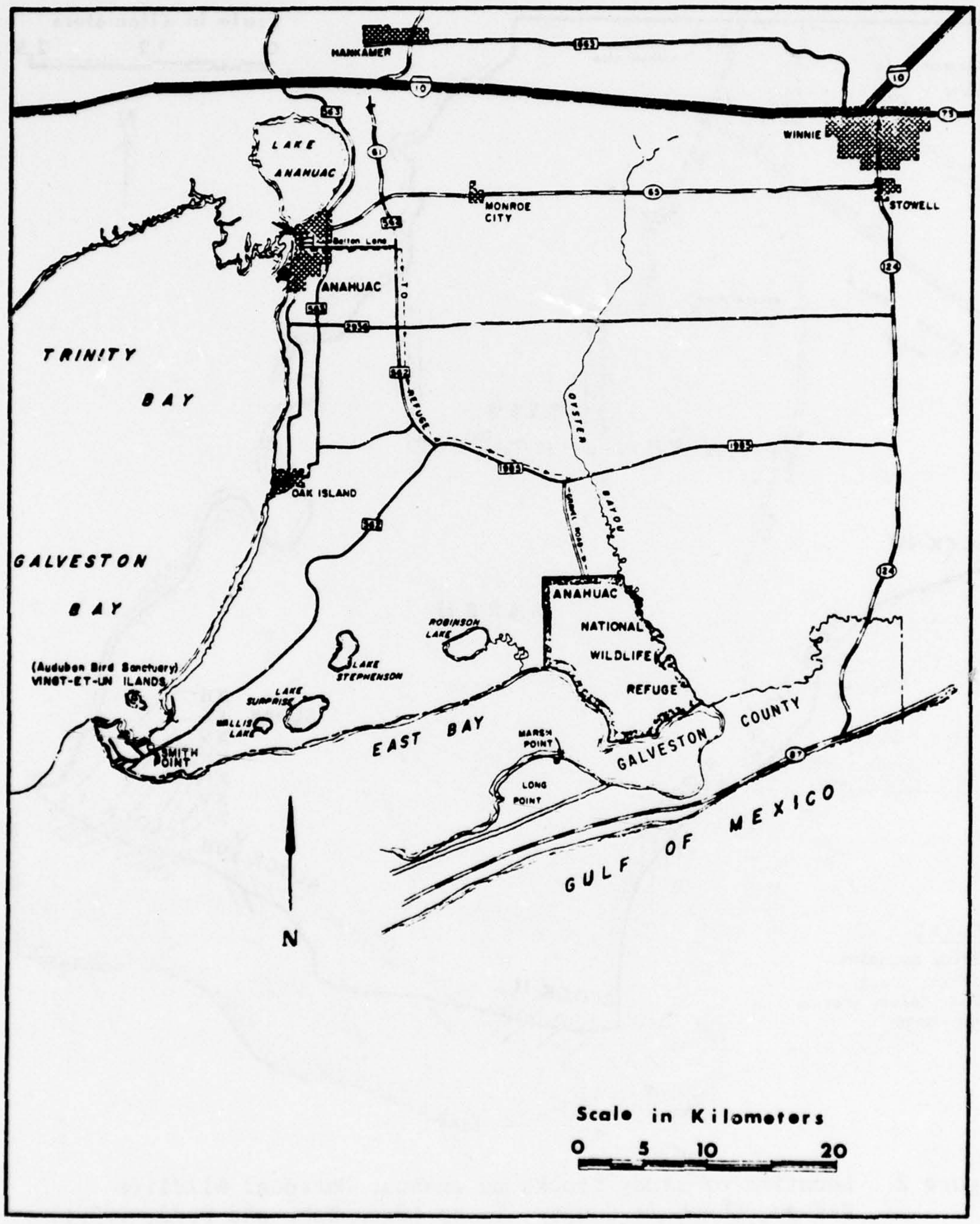

Figure 1. Location of Anahuac National Wildlife Refuge along the shoreline of East Bay (From U.S. Department of Interior).

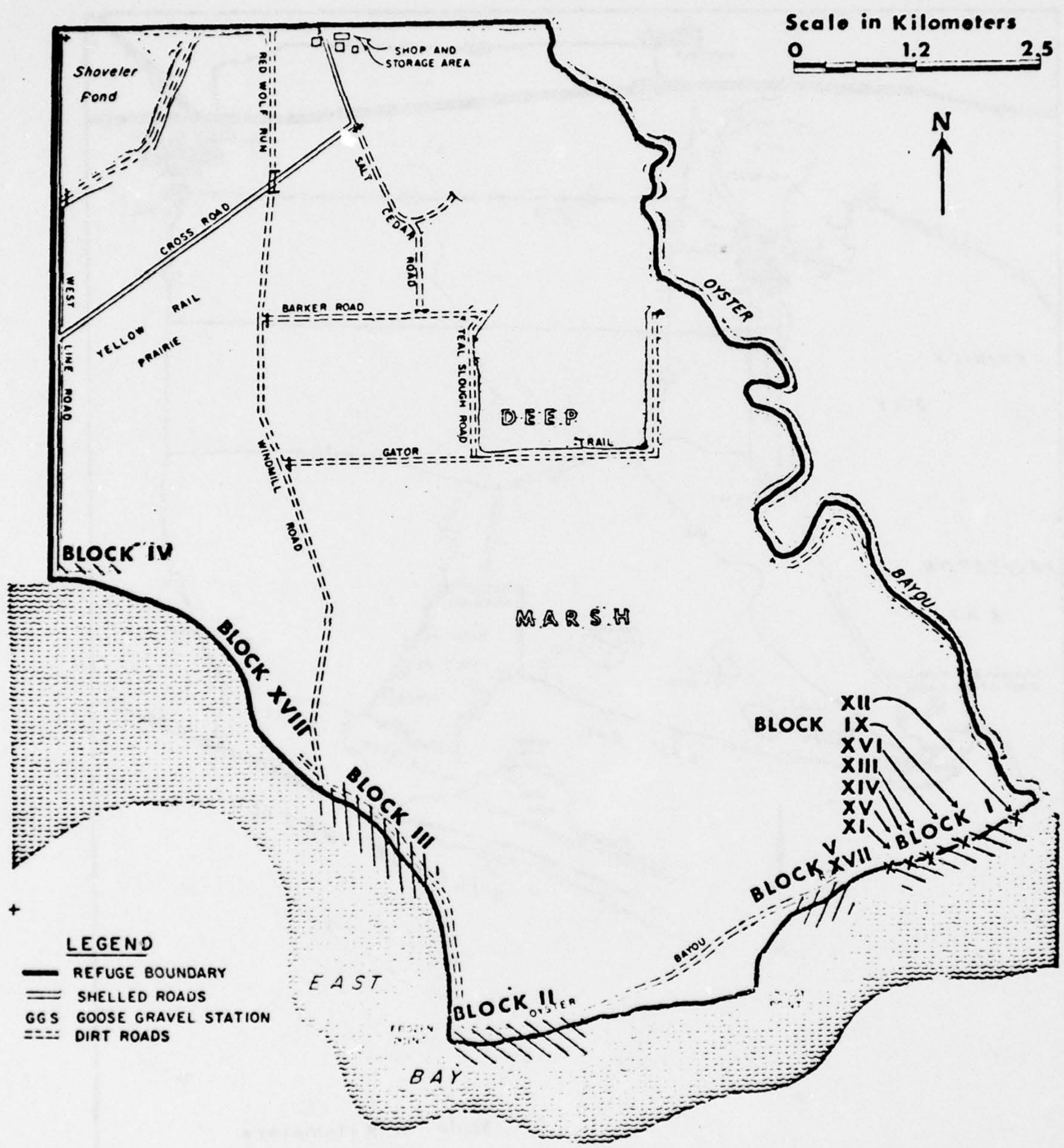

Figure 2. Location of study blocks on Anahuac National Wildlife Refuge, Chambers County, Texas (From Webb and Dodd, 1976).

and varied from 2,000 parts per million to over 18,000 parts per million during 2 years of monitoring. Soil cation concentrations reflected water salinity and the effects of evaporation from the soil surface.

Tidal ranges throughout Galveston Bay are generally less than 0.45 meter (Bobb and Boland, 1970). However, tidal amplitude is often affected by windspeed and direction. Two principal wind directions dominate the East Bay area. Persistent, southeasterly winds occur from March to 1 December and short-lived but strong northerly winds from December to 1 March (Fisher, et al., 1972). North winds in winter tend to cause abnormal and prolonged low tides. Strong southerly winds often cause abnormally high tides.

The Galveston area has relatively high humidity and receives about 102 centimeters of rain annually (National Oceanic and Atmospheric Administration, 1975). Since the vegetation and soil types change along a north-south gradient, this study was confined to the upper Texas gulf coast and more specifically to East Bay in the Galveston-Houston area.

III. PROCEDURES

Block XVII (Fig. 2) was initially sloped with a bulldozer to a 10:1 slope in March 1974 and hand-planted with 12 plant species (Dodd and Webb, 1975). All plants were washed out or killed in the lower and middle zones and a cut-bank was formed. In July 1975 this block was re-sloped to an approximate 2-percent slope. The 45.7-meter-wide planted area was protected from wave action by threading one tier of tires on a cable and attaching the cable to metal posts driven into the bay bottom. Saltgrass, smooth cordgrass, marshhay cordgrass, and gulf cordgrass were planted in rows perpendicular to the shoreline. The rows extended from below low tide to above high tide. Saltcedar (*Tamarix gallica*) cuttings were planted later. Some survival was initially recorded (Webb and Dodd, 1976). However, due to the sinking of the tires, most of this planting was lost to wave action and the remaining plants were removed.

In May 1976 a second tier of tires was placed above the existing tires (Fig. 3). A 55- by 31-meter area was planted with 48 rows of smooth cordgrass parallel to the shoreline at approximately 0.5-meter intervals. Single culms (stems) of local native plants were used as transplant material. Marshhay cordgrass, gulf cordgrass, saltgrass, and needlegrass rush (*Juncus roemerianus*) were planted in the upper half of the block. These four species were alternately placed between smooth cordgrass plants in rows perpendicular to shoreline. Planting was accomplished from 28 May to 2 June 1976. Time and cost for site preparation, construction of wave-stilling device, and planting were recorded.

The study block was divided into 10 plots perpendicular to the shoreline so that one row each of marshhay cordgrass, gulf cordgrass, saltgrass, and needlegrass rush was located in each plot. Six plots in the middle of the block were fenced with a 0.9-meter-high, 5-centimeter mesh wire to keep rabbits out.

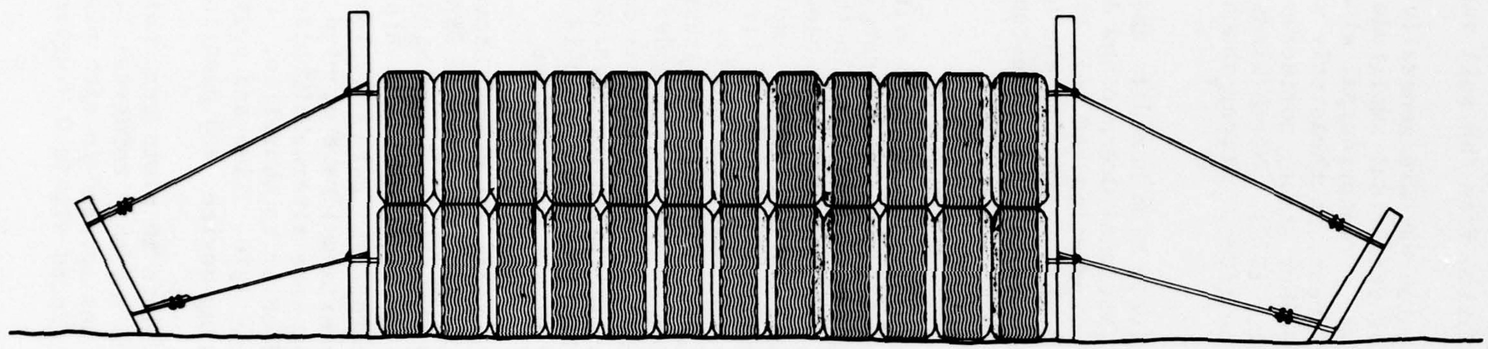

Figure 3. Drawing of two tiers of tires utilized as wave stabilizer in block XVII.

Mean low water (MLW) and MHW elevations determined in 1976 were marked with pipes. Other pipes were placed in the middle of these zones and at the northwest corners of plots. Elevations to top of the pipes and to the base were measured with a level to the nearest 0.5 centimeter.

An evaluation of the block XVII planting was made 17 August 1976. It was obvious that smooth cordgrass growth reflected differences in elevation. Therefore, during the August evaluation, survival and reproduction data were taken by rows, and then combined by five-row increments.

A second evaluation was made 25 April 1977. Elevations were determined at each metal pipe. Smooth cordgrass density was measured in 0.5-meter-squared quadrats in both the fenced and unfenced areas. Counts were converted to number of stems per meter squared. Survival of the four species planted in the upper half of the block was determined in 2.5-meter row sections. Each section included five original transplants of each species. A final evaluation was made on 23 June 1977. Procedures were the same as in evaluation two.

Evaluations and counts of plant density in blocks I to XVIII were made on 23 June 1977 to determine changes that may have occurred since initial plantings. Plant density in blocks IV and XI was determined by using ½-meter-squared quadrats. Total number of stems per plot was estimated in block XI. Estimations were based on random quadrat counts of density.

IV. RESULTS AND DISCUSSION

1. Block XVIII.

In an evaluation on 17 August 1976, mean survival of smooth cordgrass was 50.2 percent. Survival was 40.5 percent in the unfenced area and 56.7 percent in the fenced area. Indications were that rabbit predation was a problem and affected plant survival. Unfenced plots were at slightly higher elevations than the fenced. Thus, rabbit damage and drier conditions both could have been factors in plant survival.

Survival was only 7.3 percent in the five rows of smooth cordgrass at the highest elevation on 17 August. There were only 1.2 stems per surviving transplant (Table 1). Survival and reproduction for the next 10 rows (lower elevation) was below that of the 30 rows at intermediate elevations. However, it decreased at the lowest elevations (rows 46, 47, and 48). The range was from 0.4 (rows 1 to 5) to 16.4 (rows 41 to 45) plants per meter squared. The best survival, density, and tiller production was in rows 41 to 45. In the lowest rows (46, 47, and 48) wave action around and over the tires apparently was the limited factor rather than water depth.

Table 1. Summary of the 17 August 1976 evaluation of block XVII.[1]

ROWS[2]	SURVIVAL PERCENT	DENSITY (stems/m^2)	STEMS PER SURVIVING TRANSPLANT
1 to 5	7.3	0.4	1.2
6 to 10	36.8	2.8	1.9
11 to 15	54.4	4.4	2.0
16 to 20	63.5	5.2	2.0
21 to 25	63.5	6.8	2.6
26 to 30	64.3	8.4	3.0
31 to 35	56.2	8.8	3.8
36 to 40	60.4	11.6	4.5
41 to 45	69.0	16.4	5.9
46 to 48	34.1	5.6	4.0

[1] Evaluation was made 2.5 months after planting.

[2] Row 1 was at the highest elevation.

Table 2. Density of smooth cordgrass in the demonstration area, 25 April 1977.[1]

ROWS[2]	DENSITY (stems/m^2) UNFENCED WEST	FENCED	UNFENCED EAST
1 to 10	0.2	1.3	0.2
11 to 20	2.0	6.6	0.6
21 to 30	2.4	10.3	7.8
31 to 40	5.4	14.9	6.0
41 to 48	24.0	16.0	4.0

[1] Area was planted with 4 plants per meter squared in May 1976.

[2] Row 1 was at the highest elevation.

Tiller production was good at spring growth initiation. During the spring evaluation, 25 April 1977, the original rows of smooth cordgrass were no longer distinguishable at the lower elevations. An average of 15 to 16 stems per meter squared was counted at the lower elevations within the fenced area (Table 2). This was higher than in the unfenced areas, except for rows 41 to 48 on the west side of block. The overall differences between fenced and unfenced may be a measure of rabbit effects on plant establishment. Within the fenced area, density decreased as elevation increased. For example, in rows 21 to 30, stem density declined to about 10 plants per meter squared. At the highest elevations (upper 10 rows) density averaged about 1 per meter squared (less than originally planted). This indicated a low rate of survival, establishment, and vegetative reproduction above MHW.

By 23 June 1977 the number of stems had increased at the lower elevations. Figures 4 and 5 show the change in smooth cordgrass density at 1 month and 1 year, respectively. In contrast to the low survival and stem density recorded in August 1976 (Table 1), the three rows at the lowest elevation had over 100 stems per meter squared, in the fenced area (Table 3). These three rows were located on a berm formed behind the tires. Stem density declined as elevation increased. However, in rows 41 to 45 there were approximately 50 stems per meter squared in the fenced area. In contrast, less than one stem per meter squared as recorded in the highest elevation.

The effects of rabbit damage following planting were obvious at the lower elevations 1 year after planting (Table 3). Stem counts in the unprotected areas indicated a density that was less than half that of the fenced area. At the upper elevations larged differences in the stem densities inside and outside of fenced areas were not apparent.

Smooth cordgrass was much lower in stature at the higher elevations (Table 3). Maximum mean height (152 centimeters) was recorded on the fenced part of the berm next to the wave-stilling device. At the lowest elevations (rows 41 to 45) plants were not as tall as plants on the berm. Height progressively decreased as elevation increased.

Although survival of smooth cordgrass was low at the higher elevations, saltgrass, gulf cordgrass, and marshhay cordgrass had good survival percentages, 63.7, 59.5, and 73.7, respectively, in August 1976 (Table 4). Needlegrass rush had poor survival (3.2 percent). Many plants of marshhay cordgrass (47.9 percent) and some gulf cordgrass (7.9 percent) had developed seed heads by August.

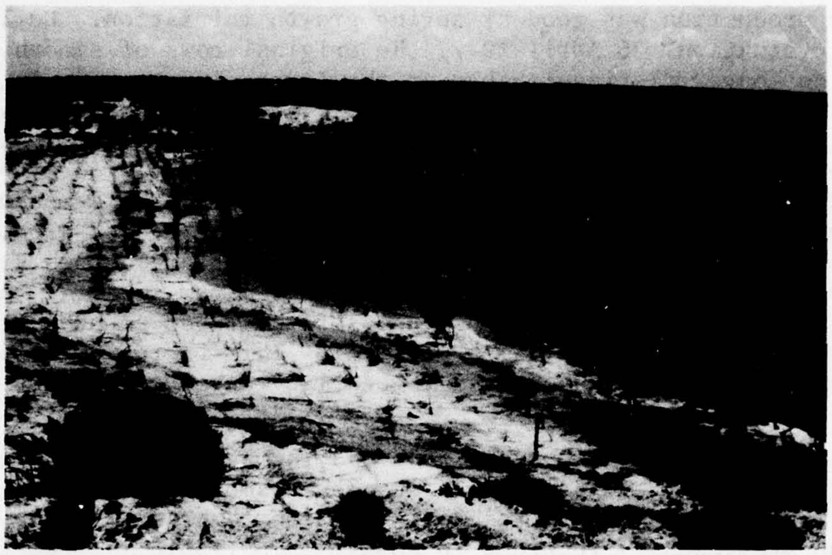

Figure 4. Block XVII 1 month after planting, June 1976.

Figure 5. Block XVII 1 year after planting, June 1977.

Table 3. Height and density of smooth cordgrass, 23 June 1977.

ROWS	Unfenced (West)		Fenced		Unfenced (East)	
	Density (stems/m^2)	Ht. (cm)	Density (stems/m^2)	Ht. (cm)	Density (stems/m^2)	Ht. (cm)
1 to 5	0	-	<1.0	24.1	0	-
6 to 10	<1.0	16.8±0.17	2.0	22.5±2.6	0	-
11 to 20	<1.0	43.1±5.5	9.1	29.8±1.9	12.0	44.9
21 to 30	9.6±1.8	76.8±11.2	22.3±5.4	83.5±6.7	15.3±5.0	59.6±9.9
31 to 40	12.8±2.7	97.5±3.3	35.5±7.7	108.4±5.9	8.8±3.1	119.3
41 to 45	11.3±3.1	121.6±6.9	50.3±8.1	119.5±7.7	5.5±5.5	118.3
46 to 48	61.8±9.3	120.1±7.0	116.8±11.3	152.2±6.4	20.0±7.8	134.4

Table 4. Percent survival of transplants in block XVII, August 1976.

Area	Smooth Cordgrass	Saltgrass	Needlegrass Rush	Marshhay Cordgrass	Gulf Cordgrass
	SPECIES				
Unfenced	40.5	57.9	0.0	76.3	49.1
Fenced	56.7	67.6	5.3	71.9	61.4
Mean	50.2	63.7	3.2	73.7	59.5

In April 1977, survival of each species was recorded by five-row increments. Percent survival in the five rows at the highest elevation was low for all species (Table 5). However, survival of marshhay cordgrass was less than 50 percent at the higher elevation and exceeded 90 percent at the lower elevations. Survival of gulf cordgrass was less than marshhay cordgrass at the higher elevations.

During the June 1977 evaluation a few plants were recorded alive that appeared dead in April (Table 5). Thus, survival was generally higher in June than April. Seed heads were present on a number of marshhay cordgrass and gulf cordgrass plants.

Elevations generally decreased slightly over time at the upper edge of the block (Fig. 6). An exception was three plots on the western side where a slight increase occurred. This increase may have resulted from soil deposited at the edge of the block during site preparation. Erosion apparently occurred at the other locations. However, elevation generally decreased less than 3 centimeters. The largest decrease was 6.3 centimeters. This erosion may reflect runoff from rain or the effects of storm tides with wave height exceeding the wave-stilling device.

In the middle zone a slight buildup of approximately 3 to 5 centimeters occurred on the east and west sides. However, a decrease of 3.1 centimeters was measured at one location. Near the wave-stilling device deposition ranged from 5.8 to 14.7 centimeters in a year.

Inundation averaged less than 17 hours daily on any part of block XVII (Fig. 7). From June 1976 to June 1977, MHW was 27.5 centimeters. This represented a 15.3-centimeter decrease in MHW from 1976 to 1977.

Table 5. Percent survival of grasses planted in rows at upper elevations of the demonstration area.

	Unfenced Area				Fenced Area			
Rows	Needlegrass Rush	Saltgrass	Gulf Cordgrass	Marshhay Cordgrass	Needlegrass Rush	Saltgrass	Gulf Cordgrass	Marshhay Cordgrass
				25 April 1977				
Upper 5	0	13.0	27.0	47.0	0	30.0	16.0	46.0
6-10	0	44.0	23.0	57.0	0	76.0	76.0	80.0
11-15	0	73.0	64.0	93.0	0	76.0	66.0	70.0
16-19	3.8	71.3	87.5	96.3	0	82.5	95.0	62.5
				23 June 1977				
Upper 5	0	10.0	40.0	75.0	0	20.0	10.0	36.7
6-10	0	35.0	20.0	50.0	0	56.7	50.0	76.7
11-15	0	70.0	70.0	95.0	0	63.4	83.4	73.4
16-19	0	91.7	91.7	100.0	16.7	83.4	91.7	87.5

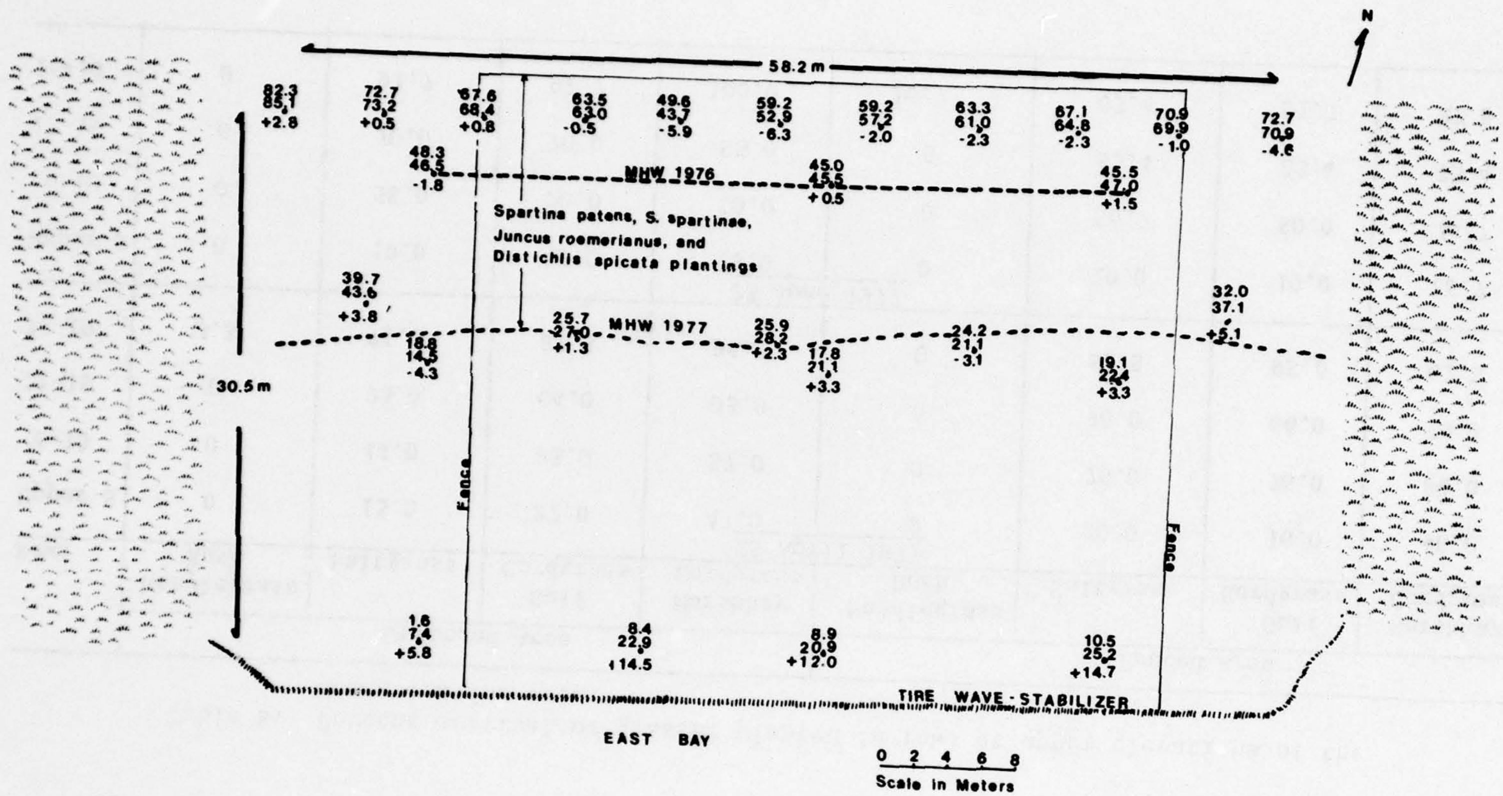

Figure 6. Elevations in centimeters taken in block XVII on 2 June 1976 (upper number) and on 23 June 1977 (middle number). Number below dot indicates gain (+) or loss (-) per the sample period.

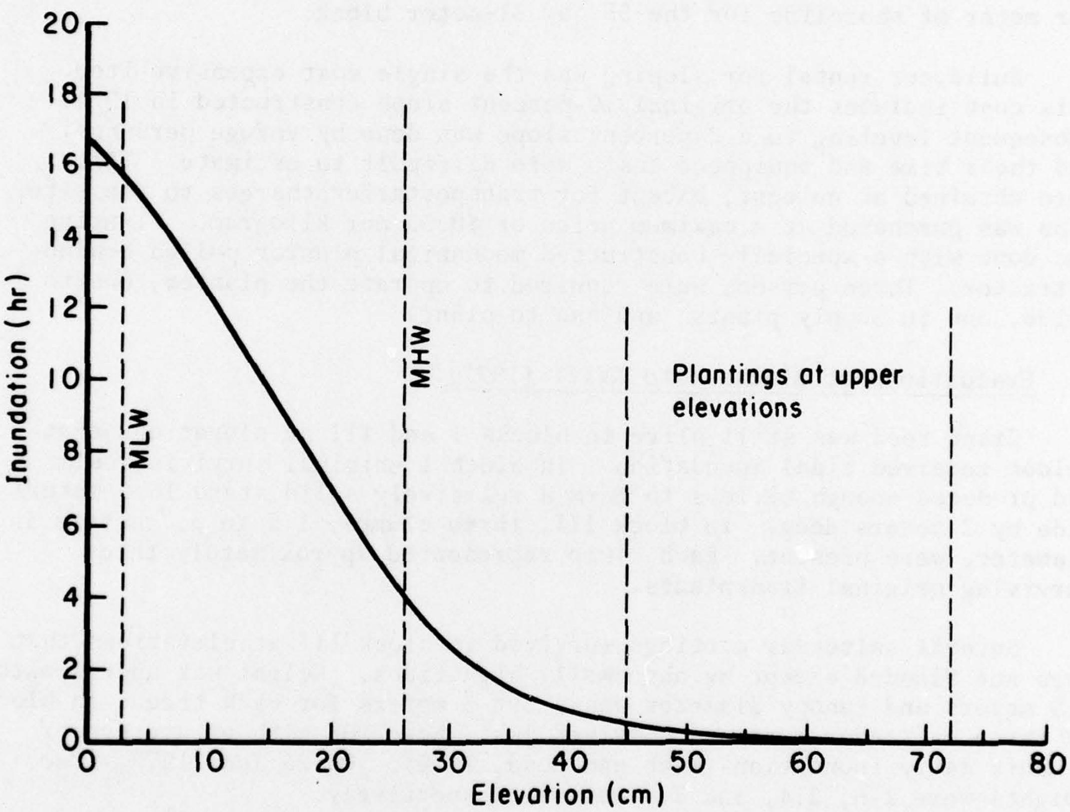

Figure 7. Mean daily hours of inundation in block XVII at each elevation from June 1976 to June 1977.

Most of the difference was caused by the extreme low wintertides. The past winter (1976-77) was severe with many hours of strong north wind that pushed the tide out. MLW was 3.1 centimeters, the lowest planting elevation.

The time and cost of constructing a wave-stilling device, sloping, and planting area XVII were calculated (Table 6). Total cost for construction of the barrier was $874.79. This was equivalent to $15.90 per meter of shoreline for the 55- by 31-meter block.

Bulldozer rental for sloping was the single most expensive item. This cost includes the original 10-percent slope constructed in 1974. Subsequent leveling to a 2-percent slope was done by refuge personnel and their time and equipment costs were difficult to estimate. Tires were obtained at no cost, except for transportation charges to the site. Pipe was purchased at a maximum price of $0.33 per kilogram. Planting was done with a specially constructed mechanical planter pulled behind a tractor. Three persons were required to operate the planter, one to drive, one to supply plants, and one to plant.

2. Evaluations of Blocks I to XVIII (1977).

Giant reed was still alive in blocks I and III at elevations that seldom received tidal inundation. In block I original surviving culms had produced enough tillers to form a relatively solid stand 16.8 meters wide by 2 meters deep. In block III, three clumps, 1.5 to 3.7 meters in diameter, were present. Each clump represented approximately three surviving original transplants.

Several saltcedar cuttings survived in block III at elevations that were not flooded except by abnormally high tides. Height was approximately 2.5 meters and canopy diameter was about 3 meters for each tree. In block IV three saltcedar cuttings survived just above MHW with an average of 2 hours daily inundation (Webb and Dodd, 1976). On 23 June 1977, tree heights were 2.6, 2.4, and 2.4 meters, respectively.

In block IV needlegrass rush had spread from surviving transplants. Diameter of the resulting clumps ranged from 0.5 to 2.6 meters. The clumps were located at approximate high tide.

Density per meter squared of smooth cordgrass in the five plots in block IV was 91.6, 88.0, 72.6, 73.0, and 63.0, respectively in June 1977. This was a significant reduction from the 216 to 300 stems per meter squared recorded in September 1975 (Webb and Dodd, 1976). In 1977, smooth cordgrass had spread 10.7 meters outside of the original plots.

Smooth cordgrass died or was washed out in all plots originally planted and exposed to direct wave action, except one. In this area the soil had been covered with rocks and shell and 10 plants survived. By August 1976 over 635 new stems had been produced. In June 1977 stem

Table 6. Time and cost for construction of wave-stilling device, sloping, and planting for block XVII.

ITEM	AMOUNT	PRICE	COST
1.9-cm Pipe	186 kg	$ 0.11/kg	$ 20.50
2.54-cm Pipe	363 kg	0.33/kg	120.00
Cable	60 m	1.96/m (est.)	118.00
1.59-cm cable clamp	5	0.80/ea.	4.00
Sloping costs	--	--	375.00
Truck rental	515 km	30.00 + 0.11/km	30.00 54.40
14 gage-size single-strand wire	152.4 m	0.006/m	1.00
Labor			
Load 375 tires	2.25 man-hours	2.50/hr	5.63
Unload 375 tires	0.50 man-hours	2.50/hr	1.25
Load 200 tires	2.00 man-hours	2.50/hr	5.00
Unload 200 tires	0.50 man-hours	2.50/hr	1.25
Construction of tire barrier	32.25 man-hours	2.50/hr	80.63
Digging Smooth cordgrass 4,138 plants	8.42 man-hours	2.50/hr	21.05
Planting Smooth cordgrass	7.33 man-hours	2.50/hr	18.33
Digging and Planting Time for saltgrass, marshhay cordgrass, gulf cordgrass, and needle-grass rush	7.5 man-hours	2.50/hr	18.75
		TOTAL	$ 874.79
		$15.90 per linear meter	

Table 7. Mean number of stems of smooth cordgrass per plot in block XI, 23 June 1977.

UNPROTECTED		PROTECTED					
1	2	1	2	3	4	5	6
0	130.5	589.5	1752.5	1310.0	708.7	162.5	0

Figure 8. Growth of smooth cordgrass in block XI, 2.3 years after destruction of the wave-stilling device. Area in the foreground was the unprotected control area.

density varied from 148 per meter squared in the densest area to 58 stems per meter squared in the sparsest area. The survival and reproduction apparently reflected protection provided by artificially placed rocks and shell. Smooth cordgrass clumps planted by refuge personnel in the past have survived in other areas with rock and shell cover (R. Clapper, personal communication, 1974).

Blocks XVII and XVIII, protected with one tier of tires, were planted in July 1975. Shortly after planting the barrier sank and was ineffective. Only one small clump of smooth cordgrass remained in each block in June 1976.

Block XI was originally protected in March 1975 with a wave-stilling device constructed of wire and hay bales; survival was only 8.9 percent in the protected areas (Webb and Dodd, 1976). Using the number of surviving transplants in October 1975 as a measure of survival, a range of 11 to 215 stems per surviving plant occurred in August 1976. By 23 June 1977 the number of stems had approximately tripled. The number of stems exceeded 1,000 per plot in several plots (Table 7, Fig. 8). It is possible that the hay deposited in the soil, or that the remaining fence modified soil parameters and wave action to allow growth and reproduction.

V. SUMMARY AND CONCLUSIONS

Survival and tiller production of smooth cordgrass occurred within the tidal zone behind a wave-stilling device constructed of two tiers of tires strung on a cable. Gulf cordgrass, marshhay cordgrass, and saltgrass survived at elevations above MHW.

Differences in survival and reproduction between fenced and unfenced areas indicated that rabbits were a problem. At elevations above MHW smooth cordgrass was not able to survive and produce tillers in sufficient numbers to stabilize the shoreline. Tillering increased with both depth and hours of inundation. No plants were subjected to more than 14 hours of inundation. The greatest tillering of smooth cordgrass occurred in the freshly deposited silt near the tire barrier.

Height of smooth cordgrass plants was greatest at the lowest elevations and decreased with increasing elevation. The plants were over 100 centimeters tall where inundation was frequent, but less than 25 centimeters where inundation was infrequent.

Survival of needlegrass rush was low. Marshhay cordgrass, gulf cordgrass, and saltgrass exhibited an 80 percent or better survival at the lowest planted elevations (approximately 0.46 meter). Inundation was less than 2 hours daily. At the highest planted elevations survival did not exceed 50 percent, regardless of species. Inundation was infrequent with a mean of 0.3 hour daily at the highest elevations. Seed heads were produced on gulf cordgrass and marshhay cordgrass in fall 1976 and in June 1977.

An approximate 0.15-meter buildup of silt was recorded 1 meter inside the tire wave-stilling device. Buildup was only about 0.03 meter in the middle area. At the upper elevations slight erosion occurred.

Generally, plants did not establish without protection from waves. Two previous plantings at block XVII without adequate protection failed. Survival followed by the development of a solid stand of smooth cordgrass occurred in block IV with protection, but smooth cordgrass failed to survive in three wave-exposed blocks. Thus, at least initial protection from wave action is needed.

Wave-stilling devices must be high enough to break most of the wave force. Two tiers of tires were required for wave-stilling devices constructed of tires strung on a cable because the bottom tier sank into the mud bottom. This also was evidenced by previous failures of plantings in blocks XVI and XVIII.

Despite the initial poor survival (8.9 percent) behind the baled hay wave-stilling device constructed in March 1975 (block XI), reproduction occurred. This device was destroyed by wave action 5 weeks after construction.

Continued growth of saltcedar plants was recorded. Tiller production of giant reed and needlegrass rush continued from plantings in 1974.

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Fort Belvoir, Virginia 22060

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The following change should be made:

Page 13 - Subheading "1. Block XVIII" should read "1. Block XVII."